BU STUDENTSHIPS 2020

PROJECT DESCRIPTION

PROJECT DETAILS
PROJECT TITLE
Computational modelling, prediction and control of the spread of aquaculture diseases with AI and network simulation
PROJECT SUMMARY

Modelling is an important tool to help understand the spread and impact of disease and provides a means through which to optimise surveillance and control measures. Social network analysis and associated modelling approaches are commonly applied tools. These approaches model the connections between individuals or locations by a variety of means and allow inferences to be made as to how rapidly a pathogen may spread through the contact network and allow individuals at high risk of getting or spreading a pathogen to be identified. A key limitation of such models is they assume the network is constant, behaving in the same way over time and in the event of a disease incursion or interventions. For example if a farmer is aware of the presence of a disease in the vicinity of their supplier, they may choose to seek another supplier, which may in turn influence that suppliers ability to supply their normal customers thus casing the network to rewire through a cascade of changes to the underlying structure. Though stochastic simulations and the addition of random connections can help reduced the consequences of this limitation, there remains a fundamental lack of understanding of behaviour response which could lead to false inferences relating to disease impacts and the effectiveness of responses.

Working with the Centre for Environment, Fisheries and Aquaculture Science (Cefas), an executive agency of the UK government's Department for Environment, Food and Rural Affairs (defra) that is responsible for the control of diseases in aquaculture in England and Wales, this PhD studentship aims to develop a dynamic network simulation model (based on an existing framework written in R) that includes behavioural responses to disease outbreaks and control measures. The project will deliver a network simulation tool that can be applied to investigate disease outbreaks and uses state-of-the-art methods and technologies from other more advanced fields to which network models are applied, such as communications and power networks. This tool will be developed in parallel to an R&D project run by Cefas and funded by defra to understand aquaculture site holder behaviours and trading patterns, which will be used to inform the network structure and its response to different key scenarios. Though focussed on aquaculture diseases, it is envisaged that the outputs from the proposed project will be applicable to a wide variety of other systems where understanding progression of an agent or process through a network is of interest.

This tool will be used directly to evaluate and inform UK government aquaculture policies and Cefas's emergency response procedures to national disease outbreaks. The outputs will also be used to help develop global biosecurity standards in aquaculture via training provided by Cefas's international centres of excellence and their OIE centre for emerging aquatic animal diseases. The project is particularly timely as it coincides with the development and implementation of the UK's National Food Strategy and Seafood 2040 which aim to increase food production and sustainability. The project also aligns with projects funded via UK government Official Development Assistance

(ODA) monies aimed at improving food (including aquaculture) standards and sustainability in low to middle income countries (LMIC). The goal is that the final tool will be applied in 'peacetime' to improve surveillance and control options, and in 'wartime' to aid the response to an outbreak.

This project will build on a social network modelling framework previously developed by Cefas through the inclusion of artificial intelligence approaches, machine learning algorithms, complex network analysis tools and latest epidemic spreading models to predict how a network may rewire and evolve in the event of a disease outbreak and subsequent control scenarios. Prior experience with machine learning and/or network simulation, and excellent coding skills in Python, R and/or MATLAB are therefore crucial.

The focus of the studentship will be to develop the network modelling algorithms and software. The student will work closely with Cefas who will collect field data on the network structure and behaviours that may occur under different scenarios of interest through information gathered via Cefas's Live Fish Movements Webservice and engagement with stakeholders.

The key output from the project will be the development of algorithms and software to:

1. Model the spread of aquaculture diseases between sites over time based on different connections e.g. live fish movements, water connections, vectors and fomites.
2. Include the consequence of seasonality and temperature on disease transmission, node state (e.g. clinical expression, sub-clinical expression) and contacts between sites.
3. Be used to evaluate the effectiveness of different surveillance and control strategies in limiting the spread and impact of a disease.
4. Predict how the contact network may change (i.e. network rewiring) in the event of a disease outbreak and control measures and adapt it accordingly.
5. Produce outputs that can be used in subsequent economic and impact assessments.
6. Be run, parameterised and updated (i.e. change the time zero contact network matrix – with a view to eventually live streaming of data directly into the model) by a non-specialist.

The work will result in a number of peer-reviewed publications relating to the methods and technologies applied to investigate disease spread. Subsequent collaborative publications will also be produced between Cefas and Bournemouth University on the application of the tool and the impacts behavioural changes have on the spread and control of aquaculture diseases.

ACADEMIC IMPACT

The fundamental research undertaken within this project will benefit the machine learning (ML) and network modelling communities. The problem of predicting the evolution of a networked system is challenging, and the applications of AI/ML to this problem are still relatively new, with many unaddressed challenges. For example, most studies focus on predicting the formation of new links but ignore the scenario of a network node disappearing. The application of the methods utilised in this project to disease network modelling is still in its infancy and this project will be at the forefront of developing a refining methods that can account for human behaviours in the event of a disease outbreak.

The algorithms and methods developed in this PhD will be applicable to a number of networked system, beyond the aquaculture sites. Hence researchers in the fields of social, food or technological networks, or any other field of study which uses (or could use) networks for modelling various underlying phenomena, will also benefit.

The academic outputs in the form of peer-reviewed publications in high-profile venues will contribute to REF, and will be used as evidence of early success in external bidding activities together with Cefas.

SOCIETAL IMPACT

The UK is one of the largest aquaculture producers in the EU (in terms of both production and value) and it is an important industry for the rural economy and society; providing jobs, food, exports and supplying recreational fisheries and the ornamental fish trade. The UK aquaculture industry directly employs circa 3500 persons and contributes around £1billion to the UK economy through direct sales of fish and shellfish, but it also supplies the pet fish trade (fish are the third most popular companion animal in the UK after cats and dogs) and recreational angling waters which as a sector contributes around £3.2 billion the UK's rural economy.

Nationally the UK has a very high health status with regard to notifiable disease which not only cause economic losses but can lead to international trading restrictions. Should a notifiable pathogen be introduced to the UK robust national control measures are implemented in order to maintain the UK's disease-free status and maintain the ability to trade internationally.

These centre around the culling, disinfecting and fallowing of infected sites, restricting live fish movements in and between affected areas and extensive testing programmes all of which are costly both to individual businesses but also the UK.

In the event of national control measures being implemented, eradication the pathogen quickly is of key importance however, maintaining trade and supply chains is also critical for the industry to survive. Tools, such as those developed in this project, that can be applied both in 'peace' and 'war' time to help optimise surveillance and controls whilst minimise impacts to site owners, consumers and taxpayers will have significant societal benefits through the development of informed policies and response plans.

DEVELOPMENT OPPORTUNITIES

The doctoral student will receive full PhD training during the project, with regular support from an experienced interdisciplinary supervisory team, where the predictive modelling and theoretical expertise from Bournemouth University will be complemented by practical experience brought by the team at Cefas. The student will have access to a number of training opportunities via the university, including:
a) participation in research seminars organised within the research group, where the student will also be expected to contribute by presenting their work,
b) sitting in selected lectures delivered within our MSc Data Science and Artificial Intelligence programme and relevant units in the Department of Life & Environmental Sciences (LES),
c) workshops provided by the Doctoral College at BU and designed to develop generic research and presentation skills,
d) attending and presenting at a number of international conferences.

The opportunities listed above will enable the doctoral student to develop a range of skills, including:
a) general research skills,
b) research methodology applicable in the research domain,
c) subject knowledge and specific methods and approaches in machine learning and complex networked systems.

The student will also have a series of development opportunities through spending time at Cefas including:

a) The opportunity to understand how government research agencies operate in comparison to academic institutions. b) Meet fish farmers and visit sites to help develop and understanding of aquaculture and disease impacts. c) Work with disease specialists and modellers to understand epidemic theory and see how computational tools are applied further understanding in this field. d) Observe national contingency planning exercises and gain exposure to policy makers to understand their drivers. e) Network with scientists across Cefas and learn how scientific computing and modelling is applied to inform UK aquatic policy. f) Attend and present at the Cefas's annual PhD student days to gain exposure and understand the breadth of Cefas's work.

SUPERVISORY TEAM	
First Supervisor	Prof. Marcin Budka
Additional Supervisors	Dr Wei Koong Chai, Dr Nick Taylor, James Guilder
Recent publications by supervisors relevant to this project	● Wahid-Ul-Ashraf, A., **Budka, M.**, & Musial, K. (2019). Simulation and Augmentation of Social Networks for Building Deep Learning Models. Retrieved from http://arxiv.org/abs/1905.09087v3 (Under review) ● Wahid-Ul-Ashraf, A., **Budka, M.**, & Musial, K. (2019). How to predict social relationships — Physics-inspired approach to link prediction. Physica A: Statistical Mechanics and its Applications, 523, 1110-1129. doi:10.1016/j.physa.2019.04.246 ● Martin Salvador, M., **Budka, M.**, & Gabrys, B. (2019). Automatic Composition and Optimization of Multicomponent Predictive Systems with an Extended Auto-WEKA. IEEE Transactions on Automation Science and Engineering, 16(2), 946-959. doi:10.1109/TASE.2018.2876430 ● Bustos, D., Jakeway, J., Urban, T.M., Holliday, V.T., Fenerty, B., Raichlen, D.A., **Budka, M.**, Reynolds, S.C., Allen, B.D., Love, D.W. and Santucci, V.L., 2018. Footprints preserve terminal Pleistocene hunt? Human-sloth interactions in North America. Science advances, 4(4), p.eaar7621. ● Król, D., **Budka, M.** and Musial, K., 2014, September. Simulating the information diffusion process in complex networks using push and pull strategies. In 2014 European Network Intelligence Conference (pp. 1-8). IEEE. ● **Budka, M.**, Juszczyszyn, K., Musial, K. and Musial, A., 2013. Molecular model of dynamic social network based on e-mail communication. Social Network Analysis and Mining, 3(3), pp.543-563. ● Musial, K., **Budka, M.** and Juszczyszyn, K., 2013. Creation and growth of online social network. World Wide Web, 16(4), pp.421-447. ● **Budka, M.**, Musial, K. and Juszczyszyn, K., 2012, September. Predicting the evolution of social networks: optimal time window size for increased accuracy. In 2012 International Conference on Privacy, Security, Risk and Trust and 2012 International Conference on Social Computing (pp. 21-30). IEEE. ● Juszczyszyn, K., Gonczarek, A., Tomczak, J.M., Musial, K. and **Budka, M.**, 2012, August. A probabilistic approach to structural change prediction in evolving social networks. In 2012 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (pp. 996-1001). IEEE. ● Juszczyszyn, K., Musial, K. and **Budka, M.**, 2011, October. Link prediction based on subgraph evolution in dynamic social networks. In 2011 IEEE Third International Conference on Privacy, Security, Risk and Trust and 2011 IEEE Third International Conference on Social Computing (pp. 27-34). IEEE. ● Juszczyszyn, K., **Budka, M.** and Musial, K., 2011, July. The dynamic structural patterns of social networks based on triad transitions. In 2011 International Conference on Advances in Social Networks Analysis and

	Mining (pp. 581-586). IEEE. ● **Wei Koong Chai** and George Pavlou, "Path-based Epidemic Spreading in Networks," IEEE/ACM Transactions on Networking (ToN), vol. 25, no. 1, pp. 565-578, February 2017. (DOI) 10.1109/TNET.2016.2594382 ● **Wei Koong Chai**, "Modelling Spreading Process Induced by Agent Mobility in Complex Networks", IEEE Transactions on Network Science and Engineering (TNSE), vol. 5, no. 4, pp. 336-349, October-December 2018. (DOI) 10.1109/TNSE.2017.2764523 ● Ge Zheng, **Wei Koong Chai**, and Vasilis Katos, "An Ensemble Model for Short-Term Traffic Prediction in Smart City Transportation System," IEEE Global Communications Conference (GLOBECOM), Waikoloa, HI, USA, 9-13 December 2019. ● **Wei Koong Chai**, Vasilis Sourlas, and George Pavlou, "Providing Information Resilience through Modularity-based Caching in Perturbed Information-Centric Networks," Proceedings of the 29th IEEE International Teletraffic Congress (ITC), Genoa, Italy, 4-8 September 2017 ● **Wei Koong Chai**, Vaios Kyritsis, Konstantinos V. Katsaros and George Pavlou, "Resilience of Interdependent Communication and Power Distribution Networks against Cascading Failures," Proceedings of the 15th IFIP Networking, Vienna, Austria, 17-19 May 2016. ● Tidbury, H.J, **Taylor, N. G. H.,** van der Molen, J., Garcia, L., Posen, P., Gill, A. B., Lincoln, S., Judd, A. & Hyder, K. (*In Press*). Social network analysis as a tool for marine spatial planning: impacts of decommissioning on connectivity in the North Sea. Journal of Applied Ecology. ● Jones A.E, Munro L.A., Green D.M., Morgan K.L., Murray A.G., Norman R., Ryder D., Salama N.K.G., **Taylor N.G.H.,** Thrush M.A., Wallace S., Sharkey K.J. (2019) The contact structure of Great Britain's salmon and trout aquaculture industry. Epidemics 100342. ● McMenemy P., Kleczkowski A., Lees D.N., Lowther J., **Taylor N.** (2018) A model for estimating pathogen variability in shellfish and predicting minimum depuration times. PloS one 13 (3), e0193865 ● Denholm S.J., Hoyle A.S., Shinn A.P., Paladini G., **Taylor N.G.H.**, Norman R.A., (2016) Predicting the potential for natural recovery of Atlantic salmon (Salmo salar L.) populations following the introduction of *Gyrodactylus salaris* Malmberg, 1957 (Monogenea). PloS one 11 (12), e0169168 ● Paterson I.K., Hoyle A., Ochoa G., Baker-Austin C., **Taylor N.G.H.** (2016) Optimising Antibiotic Usage to Treat Bacterial Infections. Scientific reports 6. ● Tidbury H.J., **Taylor N.G.H.,** Copp G.H., Garnacho E., Stebbing P.D. (2016) Predicting and mapping the risk of introduction of marine non-indigenous species into Great Britain and Ireland. Biological invasions 18 (11), 3277-3292.

INFORMAL ENQUIRIES
Please contact the lead supervisor on the following email for informal enquiries: mbudka@bournemouth.ac.uk
ELIGIBILITY CRITERIA
The BU PhD Studentships are open to UK, EU and International students. Candidates for a PhD Studentship should demonstrate outstanding qualities and be motivated to complete a PhD in 4 years and must demonstrate: • outstanding academic potential as measured normally by either a 1st class honours degree (or equivalent Grade Point Average (GPA) or a Master's degree with distinction or equivalent, in the relevant area such as data science, machine learning, data analytics or computer science

• an IELTS (Academic) score of 6.5 minimum (with a minimum 6.0 in each component, or equivalent) for candidates for whom English is not their first language and this must be evidenced at point of application.
HOW TO APPLY
Please complete the online application form by **Wednesday 30 September 2020.** Further information on the application process can be found at: www.bournemouth.ac.uk/studentships